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Fracture Statistics: Universality vs. Nucleation[1]

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We reexamine several common assumptions about fracture strength, utilizing large-scale simulations of a fuse network model and applying both renormalization-group and nucleation theory methods. Statistical distributions of fracture strengths are believed to be universal and material independent. The universal Weibull and Gumbel distributions emerge as a consequence of the "weakest-link hypothesis" and have been studied in the classical theory of extreme value statistics. These distributions are also the fixed points of a renormalization group (RG) flow. However, the engineering community often ignores the Gumbel distribution and uses the Weibull form almost exclusively to fit experimental data. Further, such fits are often extrapolated beyond the available data to estimate the probability of rare events in a variety of applications ranging from structural reliability to insurance pricing. Our recent studies of the random fuse network model raises doubts about most of these practices. We find that the emergent distribution of fracture strengths is the Gumbel distribution. However, the extremely slow convergence to the universal Gumbel form renders it unusable at least in this case. On the other hand, we show that a non-universal distribution derived by using a Griffiths type nucleation theory (due to Duxbury et al.) converges rapidly even for moderate system sizes. We find that while extrapolating the RG based universal Gumbel distribution is perilous and gives wildly incorrect predictions, the nucleation based non-universal results can be extrapolated with confidence. It is entertaining that fracture provides wonderful examples of the statistical mechanics tools developed to study both continuous as well as abrupt phase transitions.

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